

ated with display 28 (e.g., the space in which a viewer can see the display content of display 28) is merely illustrative. If desired, control circuitry 20 may manipulate layers 88 of combiner 52 to change other characteristics of head-up display 28 (e.g., field of view, color, magnification, etc.).

FIG. 7 is a cross-sectional side view of another illustrative configuration for combiner 52. In the example of FIG. 7, combiner 52 includes an array of reflectors 58 embedded in material such as index-matching material 60. Each individual reflector 58 is angled such that incoming light 70 follows the law of reflection and is reflected towards the viewer's eyes 42. Reflectors 58 may be broad band reflectors (e.g., silver reflectors, aluminum reflectors, or other suitable broad band reflectors) or may be narrow band reflectors (e.g., dichroic reflectors or other suitable narrow band reflectors). If desired, reflectors 58 may be polarization-selective.

In accordance with an embodiment, a vehicle system with a head-up display that presents output on a surface of a vehicle for viewing by a viewer in the vehicle, the vehicle system is provided that includes a door having a window, a display unit that produces display output, and an optical combiner on the window that directs the display output from the display unit towards the viewer.

In accordance with another embodiment, the optical combiner includes a holographic optical element.

In accordance with another embodiment, the holographic optical element includes a photopolymer.

In accordance with another embodiment, the holographic optical element includes a monochromatic holographic optical element.

In accordance with another embodiment, the holographic optical element includes a multi-color holographic optical element.

In accordance with another embodiment, the holographic optical element includes holographic polymer dispersed liquid crystal material.

In accordance with another embodiment, the vehicle system includes control circuitry configured to apply an electric field to the holographic polymer dispersed liquid crystal material.

In accordance with another embodiment, the optical combiner includes an array of angled reflectors.

In accordance with another embodiment, the display unit is selected from the group consisting of a light-field display unit, a liquid crystal display unit, an organic light-emitting diode display unit, an inorganic light-emitting diode display unit, a silicon display unit, a digital light processing display unit, a microelectromechanical scanned display unit, a holographic display unit, a quantum dot display unit, and a projection display unit.

In accordance with another embodiment, the combiner includes a plurality of holographic optical elements and each holographic optical element includes a hologram of at least one color.

In accordance with an embodiment, a head-up display that reflects display output off of a window in a vehicle towards a viewer in the vehicle is provided that includes a display unit that produces the display output, and a holographic optical element on the window that directs the display output from the display unit towards the viewer.

In accordance with another embodiment, the display unit includes a transmissive display with an array of pixels and a backlight.

In accordance with another embodiment, the backlight includes at least one light-emitting diode.

In accordance with another embodiment, the backlight includes at least one laser.

In accordance with another embodiment, the holographic optical element includes a photopolymer having regions with a first refractive index alternating with regions of a second refractive index that is different than the first refractive index.

In accordance with another embodiment, the holographic optical element includes a switchable diffraction grating.

In accordance with another embodiment, the switchable diffraction grating includes polymer dispersed liquid crystal material.

In accordance with another embodiment, the display unit includes a projection display unit.

In accordance with an embodiment, a head-up display that reflects display output off of a window in a vehicle towards a viewer in the vehicle is provided that includes a display unit that produces display output, and a diffractive optical element on the window that directs light towards the viewer.

In accordance with another embodiment, the window includes a side window that is located on a door of the vehicle and the diffractive optical element includes a photopolymer having regions of a first refractive index interspersed with regions of a second refractive index that is different than the first refractive index.

In accordance with another embodiment, the display unit is mounted in the door of the vehicle, light emitted from the display unit strikes the diffractive optical element on the side window at an angle of incidence, the diffractive optical element reflects the light towards the viewer at an angle of reflection, and the angle of reflection does not equal the angle of incidence.

The foregoing is merely illustrative and various modifications can be made by those skilled in the art without departing from the scope and spirit of the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. A vehicle system with a head-up display that presents visual output, the vehicle system comprising:

a side window of a vehicle;

a display unit that produces display output; and

an optical combiner on the side window that directs the display output from the display unit towards an interior of the vehicle, wherein the optical combiner is fixed relative to the display unit, wherein light from the display unit strikes the optical combiner at an angle of incidence and is directed from the optical combiner towards the interior of the vehicle at an output angle that is different from the angle of incidence, and wherein the optical combiner is configured to direct the light to at least first and second eyeboxes at different heights.

2. The vehicle system defined in claim 1 wherein the optical combiner comprises a holographic optical element having an optical interference pattern.

3. The vehicle system defined in claim 2 wherein the holographic optical element comprises a photopolymer.

4. The vehicle system defined in claim 2 wherein the holographic optical element comprises a monochromatic holographic optical element.

5. The vehicle system defined in claim 2 wherein the holographic optical element comprises a multi-color holographic optical element.

6. The vehicle system defined in claim 2 wherein the holographic optical element comprises holographic polymer dispersed liquid crystal material having an optical interference pattern.